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ABSTRACT

The following issues are examined in this monograph: (A) Should the scientific concepts that are introduced be restricted to those that are needed in describing the scientific facts the child will meet in the program or may concepts be introduced for their own sake or for the sake of demonstrating concept-development methods? (B) Should concepts or facts that are presented to the child be those that meet immediate interests--or perhaps stimulate new ones--or should they lock toward some future study of science? (C) Should the methods of science be demonstrated only in their application to scientific investigation, or will abstract demonstrations serve as well? (D) Should the elementary science program emphasize the study by the child of factual material and the observation of natural processes, or should it give the child limited experience in scientific experimentation and the development of scientific concepts and facts? (E) Should science become an important theme in skill-development programs such as reading, writing and arithmetic? (F) Should the only aim of the elementary school science program be to develop the child's understanding of scientific objectives, activities, and accomplishments, or should it instead--or in addition--be to develop the child's working knowledge of scientific concepts and facts and his proficiency in scientific methods? (BR)

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Issues in Elementary School Science

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In view of the rising interest in science education for the elementary school level, NSTA publishes this monograph for teachers and administrators. It attempts to identify some new aspects in the relationship of science to the lives of the elementary school students.

D. C. Ipsen, an elementary science specialist, is the author of several children's books.

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It has been about ten years since American scientists began to take an active interest in the elementary school science program. In those years the scientists have created new and challenging science units—sometimes too challenging. They have also created new issues in elementary school science. Although the science units have been widely discussed, the issues that came with them have not.

The program that the scientists looked at ten years ago was one they could easily find fault with. It was a program designed to do little more than give children scientific and technological information. The scientific information was perhaps not out of place in a science program; however, much of it was inaccurate or misleading. And the technological information, if it had a place in the children's education at all, surely was in the wrong program—in the view of the scientists. The usual small amount of time allowed for science shouldn't have been spent on a study that belonged in the social studies program. And perhaps most serious, the existing science program contained almost nothing that could be called a study of scientific activity. The question of how scientific information is obtained was almost wholly neglected.

The defects of the program—defects, at least, in the eyes of the scientists—gave them many options in their approaches to improving it. Some chose simply to worry about the scientific information in the program. They created teaching units that presumably gave children a clearer or more accurate or more complete view of what scientists have learned in various areas of scientific study. Others set about the usually more difficult job of creating teaching units to acquaint children with scientific activity. And some worked to create units that would accomplish both ends at once.

New Aims of the Program

Although the scientists' work is far from done, by now the new aims of the elementary school science program seem well established. The program should acquaint children both with scientific information and with scientific activity—with some of the concepts and the facts of science and with some of its methods. From looking at what some curriculum developers are doing, one might suspect narrower motives. But an experimental curriculum is often designed to emphasize only one aspect of an ultimate program and so can be misleading.

The work of the scientists, therefore, seems to be settling one of the issues. Elementary school science should be a study of various aspects of science itself and should not be concerned with the applications of scientific knowledge to other endeavors. But if the scientists are settling one issue, they seem to be introducing many more. The scientists who have contributed to various aspects of the program have also used various approaches and various philosophies. The variety of viewpoints among today's science-oriented curriculum developers is probably greater than it was among earlier socially oriented developers. Settling the biggest issue—the program orientation—still leaves many almost-as-big issues to cope with.

As a result, the science educator can easily find himself puzzled. If he tries to follow the lead of the scientists, he finds that he is led in many different and seemingly dissident directions. Now and then he may see a clear choice between the alternatives that are offered. But more often he has no better criterion than a knowledge—or expectation—of the workability of the material. Of course, until the supply of successful teaching units has grown, that criterion may be enough. But even now it should be useful to consider what besides pedagogical competence may distinguish the different new attempts at teaching elementary school science.

What follows is an examination of some of the issues of today's elementary school science curriculum. Some are issues created by new approaches to teaching science in the elementary grades. Others are issues that arise from less modern treatments that still survive. To some extent—perhaps to a large extent—they are issues that are felt to need discussion rather than issues that are currently exciting controversy. They are, perhaps, considerations that may have gotten lost in the turmoil of trying to develop workable science programs that meet even the nominal aims of the scientists.

Concepts and Facts

In discussing elementary school science it is useful to distinguish between scientific concepts and scientific facts. Unfortunately for the present discussion, the two terms are sometimes used almost interchangeably—as in one popular text series. But even though such usage has somewhat blurred it, a clear distinction can be made between the ideas.

Scientific concepts and scientific facts both derive from an observation of nature. But their relationship to nature is quite different. Concepts are the language that man has devised for describing nature. Facts are his descriptions. Concepts are the words, facts the ideas they express.

A concept, then, is an arbitrary construct. Although deriving from nature, a concept is essentially man-made. The concept of a leaf, the concept of species, the concept of energy—all of these are ideas that have grown out of the observation of nature. But in the end they are no more than arbitrary definitions that scientists have found useful in describing the universe.

A fact, on the other hand, is a deduced truth. Although expressed by man, a fact is essentially nature-made. It is a fact that the leaves of some species of oak trees are shed in the wintertime, that energy—properly defined—is conserved. Where the concepts of science are inventions, the facts of science are discoveries. Of course the discovery of facts may often depend importantly on the invention of scientific concepts needed for their expression.

Either concept or fact, if it is to qualify for scientific attention, must usually have some generality. To see a bright object in the sky is only to make an observation. To see a similar object repeatedly and to label it the sun is to establish a scientific concept. In the same way, to measure the distance to the sun and find it to be 93 million miles is only to make an observation. To repeat the observation and discover the near constancy of the distance is to establish a scientific fact.

Although concepts and facts may usually be distinguished without difficulty, their development often may not. One may hardly imagine, for example, the concept of energy and the fact of energy-conservation developing independently. Certainly the concept of energy was a very vague one until the fact was discovered that something of that sort is conserved.

The Choice of Concepts

What concepts of science should the child be taught? Little attention seems to have been paid that question, yet it would seem to raise some clear issues.

The child upon entering elementary school already has some familiarity with many of the concepts of science. Some of the narrowest or most specific concepts such as the sun and the moon are well known to him. So too are some of the broader concepts such as

a butterfly or a flowering plant, though the child's conception may not always be entirely scientific. Even some of the broadest concepts such as energy are likely not to be wholly new to the child, though usually the child's understanding of them is inadequate for most scientific purposes. Despite this initial stock of concepts, however, elementary school science programs are usually quick to introduce new ones.

It is a common practice in elementary school science programs to introduce science concepts without reference to the facts that give them meaning or significance. In one text series, for example, the children one day are taught that substances such as vinegar and lemon juice, which turn blue litmus paper pink, are called acids, and that substances such as ammonia and limewater, which turn pink litmus paper blue, are called bases. The observation is an interesting one—an unusual sort of paper is affected by different substances in different ways. But that fact by itself is hardly sufficient excuse for defining a scientific concept. Yet in this presentation no other facts are brought forth to suggest why the acid-base concept is useful. As presented, this concept derives from a trivial fact and then serves no immediate purpose. In common with many of the scientific concepts presented in the elementary school, it comes from nowhere and goes nowhere. It is almost wholly irrelevant to the life and thoughts of the child.

Sometimes a concept is given a false significance by making it assume the role of a fact. As an example, one may read in an elementary school science book that mammals suckle their young. Although certainly an appropriate comment about mammals, that is clearly not the observed fact of nature that one might infer it to be from the presentation. Since scientists have simply chosen to give the name *mammal* to animals that suckle their young, the comment alludes to an invention rather than a discovery; it is the statement of a concept rather than a fact.

But quite apart from questions of presentation, are such concepts appropriate for elementary school? Is an acid, a base, or a mammal a useful notion to a child? In fact, does he really need any new concepts at all? The child already has a fair notion of many of the things that the scientist is concerned with. The earth, the moon, a butterfly, a flowering plant, a rock, water—the child has many such concepts already. And possibly his

concepts of such familiar things are adequate for any scientific purpose he might have. Perhaps he knows all he needs to know of scientific concepts already.

Though possibly extreme, such an attitude has a reasonable basis. One might reasonably argue that the whole point of elementary school science should be to illuminate and explain the world that the child is already aware of. Acquaint him with the motion of the earth and moon, the metamorphosis of a butterfly, the respiration of a plant, the origin of a rock, the composition of water.

But one cannot go very far in dispensing such facts without finding the need for new concepts. One may say very little about water, for example, without developing a strong desire for concepts such as hydrogen, oxygen, atom, molecule—concepts that are probably largely unfamiliar to the child. One may provide perhaps too little illumination without running out of concepts that are familiar.

The question of what concepts to teach, however, could find its answer in the demands of such studies. The question could be mostly a question of facts. What concepts are involved in the facts that are important to the child? Once one decides on the facts, one is then committed to teaching certain concepts. And maybe those concepts are enough.

Facts could also influence the choice of concepts in a further way. Some facts could merely provide an excuse for talking about a concept, rather than a demand. To teach the child that butterflies metamorphose can be done without much concern for the concept of a butterfly. The child's vague idea will probably do. But still one may wish to take time to add precision to the child's concept. Even though it might add little of importance to his store of scientific information, acquainting him with the scientist's butterfly might do much to show him something of the nature of scientific classification.

But if one clings to the notion that concepts should be relevant, introducing the child to a concept such as the scientist's butterfly raises problems. What is the value in seeking an accurate definition of a butterfly? Why does the scientist care, for example, to distinguish a butterfly from a moth? While such questions can probably be answered, their need for answers—if one admits it—might make one hesitate to talk about such nonessential concepts.

Concept Development

Traditional programs have rarely given the child any clues about how scientific concepts are developed. But some of the scientists who are contributing to the elementary school program have placed first emphasis on concept development. The concepts themselves, some suggest, are a less important study than the methods that are used to get them.

Perhaps one could hope that concepts that are destined to enter the program anyway might serve as subjects for demonstrations of concept development. If the concept of an atom, for example, is to be part of the program, why not show how the concept was developed? Unfortunately, however, the concepts one most wants the children to know about usually have too complex an origin to serve as good examples of concept development. And so some curriculum developers have drawn concepts into the program more for their value as vehicles for displaying methods than for their value as useful scientific concepts in themselves.

But such introductions may perhaps be defended on philosophical as well as pedagogical grounds. Many scientific concepts have been developed with little reference to their immediate usefulness. Certainly many scientific classifications are merely speculative: they are established only in the hope that they will prove useful. And so if the development of such concepts is demonstrated honestly, it can hardly be criticized. Too often, though, the tentative nature of the concepts is not suggested.

An example of the sort of concept development that would seem to need such treatment is seen in an experimental botany unit. In the unit, children study stems of plants to discover what they have in common. With some help they can establish a concept of a stem in its relationship to other parts of a plant. They are then able to decide that with such a definition the white potato must be regarded as a stem. In the unit the investigation is dropped there, which is a good point dramatically. But philosophically it may be too soon. The suggestion that this concept of a stem is arbitrary and could prove useless or misleading is never made. The fact that the concept has apparently not proved useless but has provided insight into evolution is also left out.

But if such an approach is perhaps short on scientific content, others are much shorter. To find their vehicles

for demonstrating scientific methods, some curriculum developers actually leave the confines of science. They discard the applied approach in favor of the abstract approach. They are content to deal with essentially artificial material and to work toward ideas which cannot readily be interpreted as scientific concepts.

An abstract approach to demonstrating concept development is found in lessons of another experimental program. In one of them the children are given diffent shapes (squares, triangles, etc.) of different colors and sizes and asked to establish classifications. Though the activity has nothing directly to do with science, it presumably uses methods that a scientist might use.

Abstract approaches to dealing with concept development have the appeal of mathematics. Sorting colored squares and triangles certainly resembles some of the mathematical activities children engage in. Such activities have the advantage—if it is one—that there need be no vagueness. As in mathematics, precise answers can be put in the back of the book.

But whatever else they may accomplish, abstract approaches to concept development fail to show science in the making. With the only aim the demonstration of scientific methods, one perhaps too easily wanders away from science itself. The primary outcome of using the methods of science—the establishment of facts about the universe and its inhabitants—is easily lost sight of.

The Choice of Facts

Although no choice of facts can be made without some reference to the concepts they involve, that limitation imposes few philosophical restrictions. The biggest question, it would seem, is whether the facts are for the child that exists or for the child that is to come.

One may see in the usual selection of facts for elementary school consumption a concern for their usefulness in later studies. To know that a hydrogen atom consists of a proton and an electron is not going to solve any of the problems of the child's life today, but it may make some later course in science more easily comprehended.

But should only the future child be served? Should one perhaps instead stay with the facts of science that relate to the child now? Facts might be selected only to show the child what science accomplishes for him.

Some of the facts of science are immediately useful to the child. If a child can learn that a moving car

has a momentum which cannot be removed from it instantaneously, his learning may be useful in saving his life on the streets. But probably not much of the science a child can learn will have that immediate usefulness.

Other facts may serve to illuminate the familiar, even though they serve no immediate use. Scientific facts about the human body or about plants or about the stars show children what science may reveal about things in their lives. And of course facts about the hydrogen atom might show that, too.

But probably neither the useful nor the illuminating are consistently important facts to the child. In the end the important facts are those that appeal to his immediate interests. First of all, science should tell him something he wants to know. Perhaps dinosaurs are to be preferred to dynamics.

This criterion of child interest could rule out several types of facts found in current programs. One type is the over-familiar. A common textbook demonstration is to grow two bean plants and then deny water to one of them. One wilts, which presumably shows that plants need water. Since every child in the classroom knows that the unwatered bean plant will wilt, it is hardly a thrilling demonstration. Of course it might still be an interesting one if children generally have not observed plants wilting. But for many children it must prove a trivial and unexciting experience.

The other scientific facts that might be questioned on the basis of the child's interest, if no other, are at the other end of his knowledge. How many of the sophisticated facts that are now being put forward to the child can be made sufficiently interesting? Is the fact that energy is conserved, for example, something that can excite the elementary school child?

But with facts as with concepts, perhaps the demands of demonstrating their development may have the primary influence on their choice.

Fact Development

The facts of science are developed by observation and experimentation, which sound like processes that can surely be performed in the elementary school classroom. But developing real facts of science is typically a slow and difficult process. Whether children can effectively mimic the ways of the scientist here is surely a question.

Probably children may come closest to the scientist in observation. They may simply inspect nature. Through observing a caterpillar transform into a butterfly and attempting to record what they see, they may learn much about a scientist's problems of observation and communication.

After a fashion, children may also experiment. They may do more than observe a situation passively: they may observe a situation which they manipulate. The children's experimentation, however, is not likely to be very productive scientifically. They may often do little more than explore a situation experimentally and become aware of problems of measurement and control.

Occasionally children may reach a much more sophisticated level of fact development—the actual establishment of scientific facts. Relatively little attention has been paid to developing such activities for the classroom. Some of the curriculum-development projects, however, have made significant contributions. One example is a unit in which children experiment with mealworms to discover their behavior traits. The children subject the animals to various influences and observe how they react. Another example is a unit in which children experiment to discover possible functions of various animals' colorations. Using models of animals, they discover what sorts of colorations conceal or reveal the models. Both of these units acquaint children with methods of science in their application to actual scientific investigations.

Probably because of the difficulty in finding good scientific applications, abstract approaches to acquaining children with fact-development methods are also being tried. Some of the curriculum developers have devised experimental situations in which the scientific content is secondary or absent. In units from one program, for example, children experiment with batteries and lights or with leaky bottles. In their experimentation with such equipment, they gather data; but the possible scientific value of the data is usually negligible.

Abstract approaches to demonstrating fact development usually cannot have the tidiness of abstract approaches to demonstrating concept development. Trying to uncover facts about a leaky bottle or about electrical circuitry is likely to be a haphazard process. Although certain answers may be anticipated, usually no clear goal is defined. By careful choice of materials

and objects, however, a relatively clean situation can be presented to the child. In particular, the number of variables he must cope with can be kept low. This greater chance of control could make the abstract approach more popular than the applied. But of course in the minds of some, the artificiality could be too strong a disadvantage.

Some of the choices in demonstrating fact development are matters of philosophy or pedagogy. But some may be more matters of schedule. In fact, how all the aspects of science are treated in the elementary school may depend importantly on both the amount of time and the sorts of time that are available for science.

Room for Science

If none of the aspects of science is neglected, its study in the elementary school classroom demands four almost distinct activities. The four make significantly different demands on teacher, children, and materials.

The first activity may be termed *study*. If the children are to become acquainted with a generous number of the concepts and facts of science, they may efficiently and effectively learn of many of them from books. Books also can be useful in acquainting the children with the methods of science through presenting accounts of scientists' work. Thus study activities may serve to reveal both the concepts and facts of science and the methods of developing them.

A second activity may be termed *observation*. Despite the usefulness of books, some firsthand gathering of scientific information will continue to be an important part of any effective elementary school science program. A typical observational activity is to watch the development of an organism—for example, the transition of tadpole to frog—and then to write a description of what happened. Though probably of most use in revealing or suggesting facts of science, direct observation is also of some use in revealing methods of science—particularly fact-development methods.

A third activity is *experimentation*. Even though observational activity does give the children firsthand experience with the way in which scientific information can be gathered, it fails to reveal many other important methods of science. To experience these the child must manipulate the observed material. While carefully structured experiments are often used

for this purpose, more useful may be freer experiments in which the child actually seeks new facts of science.

A fourth activity may be labeled *development*. The bigger ideas of science—whether concepts or facts—must be developed slowly and carefully. They require a teacher-involvement that is likely to be much greater than in any of the preceding activities. To develop the meaning of a concept such as force or to establish the reasonableness of a fact such as Newton's Third Law of Motion, a lot of classroom discussion, demonstration, and experimentation seems almost essential. Books may certainly help, and observation and experimentation may provide useful background. But in the end, demonstrating and discussing must do much of the job of developing the more unfamiliar concepts and the more complex facts.

In the traditional programs, greatest emphasis has been placed on study and observation. True experimentation is usually absent, and although some attempt at development of ideas may be present, discussion and demonstration usually serve instead simply to emphasize concepts and facts presented in the study and observational phases of the program, rather than to develop them. Also such activities are often omitted or abbreviated in classroom presentation.

In the typical new program, the emphasis is turned around. Study and observational activities are usually greatly reduced, and most of the available time is turned over to experimentation or to development.

These seeming slights on the part of old and new programs might be avoided if more use were made of other parts of the school week besides the science hours. The subject matter of science could well serve as content for other studies in the elementary school.

Reading is the most obvious study that might make use of science. It is often proposed that the large amount of study that is useful for science could become an effective part of the reading program. Children usually learn to read through stories about social activities, or sometimes fantasies. Although these stories may have value for children, most of that value would be found also in stories about science or scientific activities—stories that could serve the aims of science instruction as well. And for some children, certainly, motivation would be improved. This approach would pace the child's accumulation of sci-

entific information to his reading progress, which may be a reasonable thing to do.

Also able to accommodate scientific content is the writing program. Ideal content for it might be provided by the observational portion of the science program. In a proper program devoted to scientific observation, much of the children's activity is the writing down of their observations. That writing could well become a major part of the children's writing program—particularly in the earliest grades.

The arithmetic program may also make some contribution to science. Some incidental learning is of course possible through dealing with problems that involve scientific concepts and facts. But perhaps more significant might be the inclusion of problems on concept development. In fact, abstract approaches to concept development would seem to fit more easily and logically into a mathematics program than into a science program.

With the science hours freed in these ways of the study activities and the observational activities—along with some of the abstract developmental activities—all of the science time could be devoted to experimentation and development.

The moment for such a multichannel approach may not be here. But as more of the necessary books and guides become available, the establishment of an articulated elementary school program that gives science its due can perhaps be contemplated.

One of the problems with finding room for science is that its objectives in student performance are far from clear. With many other more specific demands to compete with, the loosely defined demands of science are easily ignored. The obvious question is whether the science program should have specific goals of competence.

Competence in Science

Unlike reading or arithmetic, science in the elementary school is a subject without standards of student performance. In reading and arithmetic, some level of proficiency is a necessary outcome of any adequate program. Should it be in science?

Scientific proficiency can take two forms—knowledge of some of the important concepts and facts of science, and skill in the use of some of the basic scientific techniques. Until recently, the first of these proficiencies was the only one significantly pursued. But

now the second is drawing attention, particularly in some of the experimental programs. In them, the ability to function scientifically is often rated well above the ability to recall scientific information.

But the more important issue may be whether proficiency of any sort is a useful goal. Some feel that the only proper function of the science program in the elementary school is to develop the child's understanding of science. The child needn't become a storehouse of scientific concepts and facts nor an expert in scientific methods. But he should gain an appreciation of what science is and does. Only then will he be properly prepared to assimilate the often dogmatic scientific learning to come. If such an understanding of science is the proper goal of elementary school science education, the child may properly be confronted with many concepts, facts, and methods, but without any time-consuming memorization of them or lengthy drill in their use.

A possible question is whether the child may gain an acceptable understanding and appreciation of what science is or does without some proficiency. Can one understand the concepts and facts of science without many of them securely stored in one's brain? Can one understand the methods of science without first acquiring some expertness in their use?

With understanding the goal, however, the choice of topics and approaches would surely be significantly different. Wholly abstract approaches would probably be discarded. Unless it were tied in with actual scientific activity somehow, there would seem to be little point in sorting colored squares.

But if understanding should be the goal, setting standards of performance becomes difficult. It is a simple matter to test the child's ability to sort squares. It is harder to test his understanding of how and why leaves are defined as they are.

Conclusion

From this inspection of some of the alternatives for science education in the elementary school, one becomes aware of a number of potential issues. The following are the most conspicuous:

1. *The role of concepts.* Should the scientific concepts that are introduced be restricted to those that are needed—or at least usable—in describing the scientific facts the child will meet in the program, or may concepts properly be introduced for their own sake

or simply for the sake of demonstrating concept-development methods?

2. *Immediate interests* vs *future needs.* Should the concepts or facts of science that are presented to the child be those that meet his immediate interests—or perhaps stimulate new ones—or should they look toward some future study of science?

3. *Abstract* vs *applied.* Should the methods of science be demonstrated only in their application to scientific investigation, or will abstract demonstrations serve as well?

4. *Study* vs *experience.* Should the elementary school science program emphasize the study by the child of factual material and the observation of natural processes, or should it give the child limited experience in scientific experimentation and the development of scientific concepts and facts?

5. *The role of science.* Should science become an important theme in skill-development programs such as reading, writing, and arithmetic?

6. *Understanding* vs *proficiency.* Should the only aim of the elementary school science program be to develop the child's understanding of scientific objectives, activities, and accomplishments, or should it instead—or in addition—be to develop the child's working knowledge of scientific concepts and facts and his proficiency in scientific methods?

It can possibly be argued that all of these issues are really side issues of little concern right now. The important question—in the minds of some, at least—is not so much what or how, but whether. Science of any sort, they argue, is better than none. Any study that is stimulating and is also science-oriented or at least science-inspired is appropriate fare for the elementary school science program. And certainly such a study may well be better than much that passes for science study today. But should it be the goal? Can no higher achievement be aimed for?

This statement of issues is an attempt to encourage the consideration of higher goals. But even if it fails in that, perhaps it may still be a step toward a clearer identification of some of the alternatives in philosophy and approach in the teaching of elementary school science.